DESIGN AND ANALYSIS OF THE SUPPORT STRUCTURE FOR AN OPEN CHANNEL FLUME

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

Open channel flumes which will be built on the ground level need a support structure to minimize the displacement at the sidewall due to the hydrostatic and dynamic pressure of water. The objectives of the study are to evaluate the pressure at the sidewall of the flume, and to design a supports structure for the sidewall of the flume under certain flow conditions. Three basic designs were selected and drawn using Solidwork software and solved with the Autodesk Simulation Multiphysics solver. From the data obtain it shows that Design 1 with 0.5 m breadth, 0.44 m length and 21 of support structure by using Ready Mix Concrete Normal Mix Grade 30 gave the smallest value of wall displacement, and 81.73% effectiveness of the support structure. Simulation result shown that the flume did need a support structure to reduce the displacement of the sidewall. As a conclusion, Design 1 as it gave the desirable result with the acceptable cost involved, effectiveness and economically.

ABSTRAK

Saluran air terbuka yang akan dibina di atas paras tanah memerlukan struktur sokongan untuk mengurangkan anjakan di sisi akibat tekanan hidrostatik dan dinamik air. Objektif kajian ini adalah untuk menilai tekanan pada dinding sisi saluran air, dan mereka bentuk struktur sokongan untuk sisi saluran air di bawah keadaan aliran tertentu. Tiga reka bentuk asas telah dipilih dan direka menggunakan perisian Solidwork dan diselesaikan dengan penyelesai Simulasi Multiphysics Autodesk. Dari data yang diperolehi menunjukkan bahawa Reka Bentuk 1 dengan 0.5 m lebar, 0.44 m panjang dan 21 struktur sokongan dengan menggunakan Konkrit Sedia Bancuh Bancuhan Biasa Gred 30 memberi nilai terkecil anjakan pada dinding, dan keberkesanan 81.73% kepada struktur sokongan. Hasil simulasi menunjukkan bahawa saluran air memerlukan struktur sokongan untuk mengurangkan anjakan sisi. Kesimpulannya, Reka Bentuk 1 kerana ia memberikan hasil yang diingini dengan melibatkan kos yang boleh diterima, keberkesanan dan dari segi ekonomi.

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LIST OF SYMBOLS

A	Area
Pa	Pressure
g	Gravity
a	Acceleration
F	Force
l	Length
n	Number
V	Volume
ρ	Density
ħ	height
%	Percentage
m	Meter
v	velocity

LIST OF ABBREVIATIONS

2D	2 Dimensional
3D	3 Dimensional
CIDB	Construction Industry Development Board Malaysia
FEA	Finite Element Analysis
UMP	University Malaysia Pahang
SSF	Sliding Safety Factor
TNB	Tenaga Nasional Berhad

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Renewable energy refers to the energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat which is naturally replenished. Renewable energy can be particularly suitable for developing countries. In the rural areas, the transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Therefore by producing the renewable energy resources locally, it can offer a viable alternative.

Renewable energy projects in many developing countries have shown that the renewable energy can contribute directly to poverty alleviation by providing the energy needed for creating businesses and employment. Through renewable energy also, it can contribute to education by supplying electricity to schools.

1.2 BACKGROUND OF STUDY

In this modern era, vast amount of energy required to generate electricity. The energy is used to power up machines, supplying electricity to the residential area, and to move vehicle. Since the finding of fossil fuel, it's being started to use it until now as main source of energy. In Malaysia, in the early eighties, oil-fired generators were used to produce electricity. As years passing by Tenaga Nasional Berhad (TNB) had found alternative resources, and the oil requirement has reduced over the years. Most of the time, fossil fuels were depends too much; therefore renewable energy resources must be obtained. In this chapter, the problem statement, objective, hypothesis and scope of study will be explain in detail.

1.3 PROBLEM STATEMENT

In rural and remote areas, it is always hard to supply the continuously stable electricity to the population. A steady supply of fuel would be required to generate electricity as generator was using fuel. This will be a problem in term of cost as nowadays the price of fuel is increasing. Therefore, as an alternative, a micro-hydro turbine will be installed to supply electricity in these areas.

Before an actual size of the mini-hydro turbine could be fabricated, a model scale of micro-hydro turbine would be required to be built and tested. Therefore, a flume needs to be developed in order to simulate the river flow, and test the turbine to find the potential amount electricity to be generated, and the efficiency of the system.

The flume will be built on the ground; therefore, it has no support structure to sustain the pressure of water at the wall. Hence, building the side support structure to sustain the hydrostatic and dynamic pressure of the water and analysis of it will essential to consider.

1.4 OBJECTIVE

The objectives of the study are:

i) To evaluate the pressure distribution at the sidewall of the flume.

ii) To design a support structure for the sidewall of the flume.

iii) To analyse the effect of support structure on the displacement of sidewall of the flume.

1.5 SCOPE OF PROJECT

The scope of the study are:

i) To evaluate the pressure distribution at the sidewall of the flume.
ii) To perform a structural analysis upon the support structure.
iii) Run a simulation of static and dynamic pressure of water upon the flume wall.
iv) To analyse the possible three design of the flume support structure.
v) Concrete will be used as the material of support structure.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter includes the study of the water flume from various sources. In this chapter also, the design for a support structure of the flume could be determined

2.2 OPEN WATER CHANNEL FLOW FLUME

In order to simulate the flow of a river, an open water channel flow flume need to be build. The open water channel had been used in the Otago University for aquatic research such as swimming. The swimmer will not move if he/she swim in the swimming flume, as the water being pumped into the swimming flume. The amount of water will be constant as the water move in a circulation flow. Therefore, thorough research being done by Robbin Britton (1998) to keep the water flow stable. Besides that, according to Robbin Britton (1998), the swimming flume can be used to test kayak and canoe. In the upcoming research, this water channel could be used to simulate a lab scale wave or tsunami.

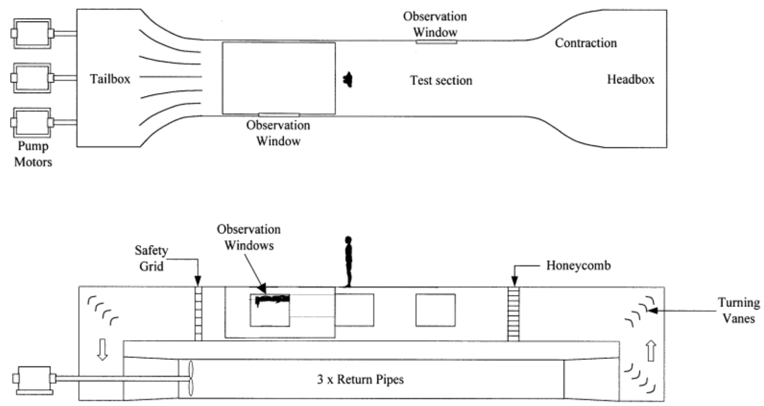

Figure 2.1: Schematic views of the swimming flume at Otago University

Source: Britton (1998)

Figure 2.1 shows the schematic views of the swimming flume at the Otago University. The test section of the swimming flume used by Otago University is rectangular shape channel and material used is fiberglass, stainless steel and mild steel. Even though, fiberglass has the advantage of lightweight and easy to install but the cost is high. Therefore we have come to an option to choose concrete as our material in term of cost.

In the early days, water channel were used to transport log from the cutting area to the processing area. Now, the water channels are widely used in the drainage system as shown in Figure 2.2. This will help to flush out the rain water during rain and prevent flash flood in a larger city. For example in Kuala Lumpur, when it is raining a flash flood always occur due to the poor drainage system, therefore the building of the open water channel help the flow of rain water and preventing the flash during raining season.

Figure 2.2: Water channel for Klang River in Kuala Lumpur

Sources: HUME Concrete Marketing

2.3 COUNTERFORT RETAINING WALLS

The water channel will be place at the ground level. As being told before, the water channel is similar to the drainage system which uses concrete as their main material to build it. Figure 2.3 shows the drainage system and the outer sidewall of the drain is being supported by the soil. Meanwhile in our case there will be no soil to support the sidewall as shown in figure 2.4. As we know the pressure at the bottom of the water channel will be the highest. Since the thickness of the wall of the water channel is the same therefore a counterfort retaining wall had been considered in our design to support the sidewall of the water channel.

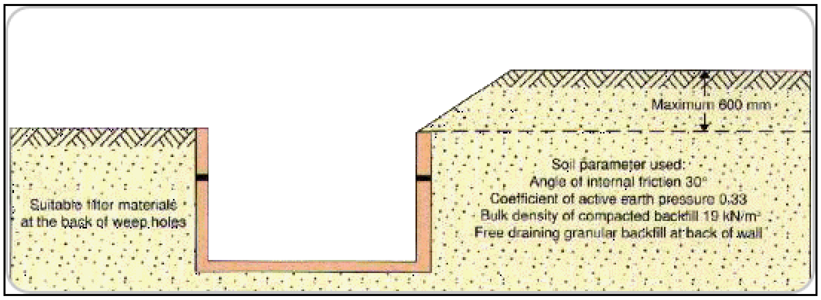

Figure 2.3: Water channel for drainage system

Sources: HUME Concrete Marketing

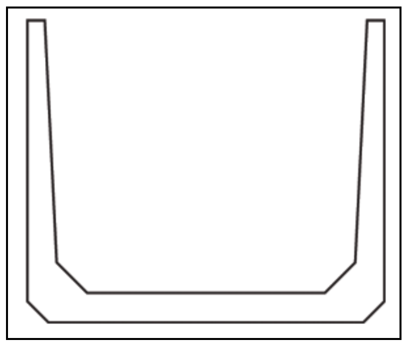

Figure 2.4: Water channel on a ground level without counterfort wall

Sources: HUME Concrete Marketing

According to M. Ghazavi (2003), in his journal he stated that to design a counterfort retaining wall there is some standard that must be followed to determine the stem thickness, base thickness, distance between counterfort, counterfort thickness and lengths of toe and heel. By following the method and parameter suggest by M. Ghazavi as shown in table 2.5 we could determine the size and design of our counterfort retaining wall. Table below shows the lower and upper bound of the design variables for the counterfort walls

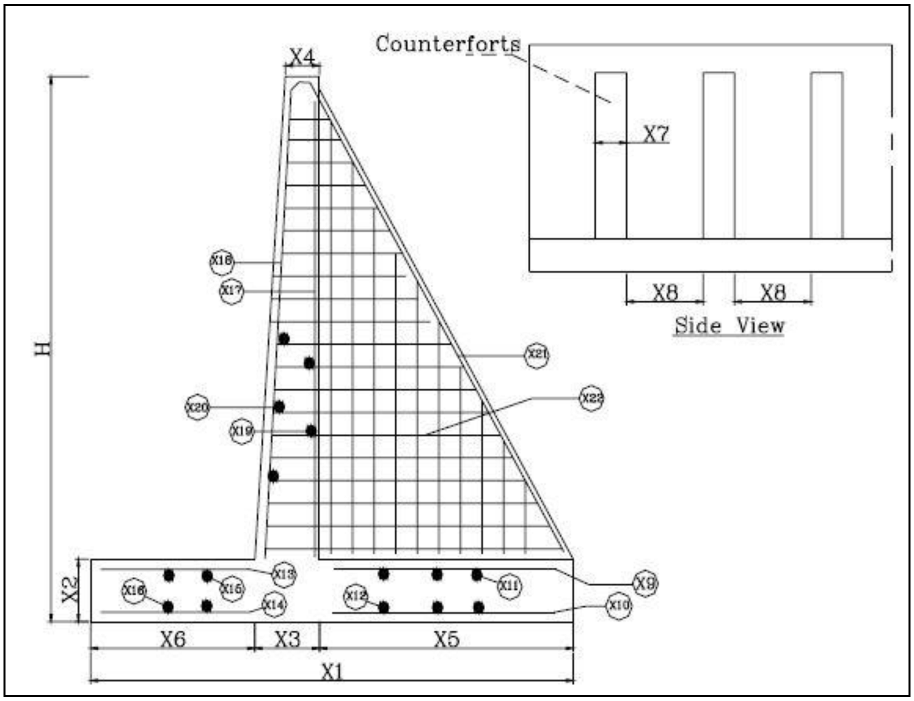

Figure 2.5: Design variable for typical reinforced concrete counterfort retaining walls

Source: Ghazavi (2003)

Table 2.1: Lower and upper bounds of design variables

Lower bound	Upper bound
X_{1min}=0.3H	X_{1max}=3H
X_{2min}=H/10	X_{2max}=H/8.5
X_{3min}=H/10	X_{3max}=H/8.5
X_{4min}=20 cm	X_{4max}=30 cm
X_{5min}=0.1H	X_{5max}=2H
X_{6min}=0.1H	X_{6max}=H
X_{7min}=20 cm	X_{7max}= 50 cm
X_{8min}= 0.3H	X_{8max}= 0.7H
X_{9min}= minimum of shrinkage and temperature rebar at heel in x direction	X_{9max}= maximum of shrinkage and temperature rebar at heel in x direction
X_{10min}=minimum of shrinkage and temperature rebar at heel in x direction	X_{10max}= maximum of shrinkage and temperature rebar at heel in x direction
X_{11min}= minimum of shrinkage and temperature rebar at heel in y direction	X_{11max}= maximum of shrinkage and temperature rebar at heel in y direction
X_{12min}= minimum of shrinkage and temperature rebar at heel in y direction	X_{12max}= maximum of shrinkage and temperature rebar at heel in y direction

X_{13min}= minimum of shrinkage and temperature rebar at toe in x direction	X_{13max}= maximum of shrinkage and temperature rebar at toe in x direction
X_{14min}= minimum of shrinkage and temperature rebar at toe in x direction	X_{14max}= maximum of shrinkage and temperature rebar at toe in x direction
X_{15min}= minimum of shrinkage and temperature rebar at toe in y direction	X_{15max}= maximum of shrinkage and temperature rebar at toe in y direction
X_{16min}= minimum of shrinkage and temperature rebar at toe in y direction	X_{16max}= maximum of shrinkage and temperature rebar at toe in y direction
X_{17min}= minimum of shrinkage and temperature rebar at stem in z direction	X_{17max}= maximum of shrinkage and temperature rebar at stem in z direction
X_{18min}= minimum of shrinkage and temperature rebar at stem in z direction	X_{18max}= maximum of shrinkage and temperature rebar at stem in z direction
X_{19min}= minimum of shrinkage and temperature rebar at stem in y direction	X_{19max}= maximum of shrinkage and temperature rebar at stem in y direction
X_{20min}= minimum of shrinkage and temperature rebar at stem in y direction	X_{20max}= maximum of shrinkage and temperature rebar at stem in y direction
X_{21min}= minimum of inclined rebar at counterfort	X_{21max}= maximum of inclined rebar at counterfort
X_{22min}= minimum of shear rebar at counterfort	X_{22max}= maximum of shear rebar at counterfort

Source: Ghazavi (2003)

With the parameter obtained from the research of M. Ghazavi (2003), not all of it will be used in the study to design the support structure of the sidewall of the water channel. With the useful information, we could design the counterfort easily and later we could run a simulation to test the design whether the counterfort wall could sustain he pressure from the water.

2.4 SLIDING SAFETY FACTOR

In Figure 2.6 show the front view of the water channel which is similar to concept of a wall of a dam. Wall of a dam is thicker at the bottom compared at the surface. This due to the concept of pressure, as we go deeper in the water, the pressure will increase. Therefore, that’s why the wall is always thick at the bottom to sustain pressure.

But even though, the bottom of the wall is thick, we should never neglect the possible damage that might affect the design. One of the potential threats to the design is crack. According to Farrokh Javanmardi (2004) whenever there is a crack at the inner of dam, the pressure which comes from the water will push the water into the crack hence making a new crack opening and filling the void. As this process continues, the crack will be increasing and the length of crack is denoted as L_{cr}

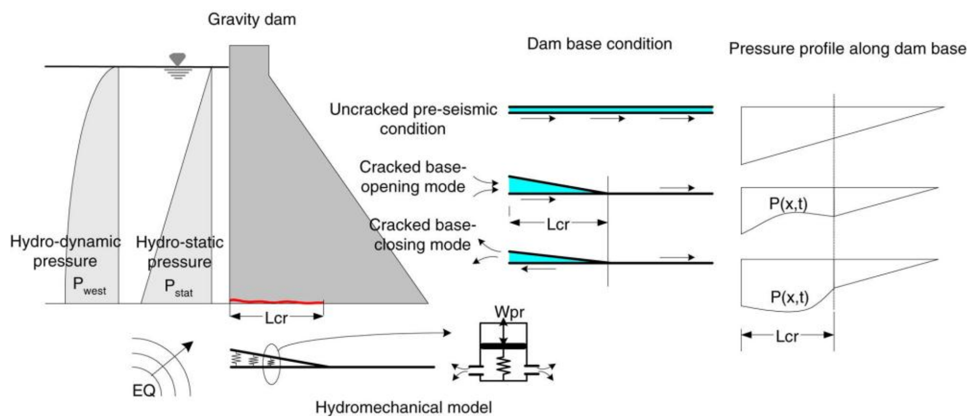

Figure 2.6: Static and transient uplift pressure

Source: Javanmardi (2004)

Sliding Safety Factor (SSF) is the factor of safety against sliding on the sand layer beneath the footing (J. Michael Duncan, 1999). From Farrokh Javanmardi research he applied the SSF in his study to show the movement of the dam when there is a crack. Therefore we could use this method to determine whether the wall of the retaining wall will crack or not. The shape of the flume is U-shape, therefore is does not have a sand layer footing as stated by Farrokh Javanmardi (2004) in his journal. Even though it does not have a sand layer footing, but the method could be applied to this study

2.5 FLUID STRUCTURE INTERACTION PROBLEMS

In this paper, Damodar Maity (2003) discuss about the finite element analysis of the fluid structure system by considering the couple effect of elastic structure of fluid. The study was held to determine the condition of the dam structure. Due to the complex topographical condition of dam structure, finite element method is recognized as one of the powerful numerical tools in most practical problem (Maity, 2003)

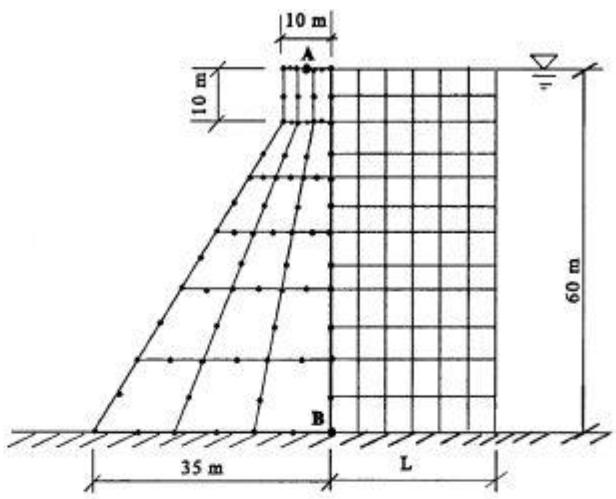

Figure 2.7 Geometry and finite element discretization of dam

Source: Maity (2003)

Damodar Maity (2003), stated that at the top of the dam is made slightly thicker. This is to prevent greater displacement at the top of the dam. Figure 2.7 shows the thickness the top of the dam wall. This design could be used as one of the design for the support structure of the flume. The concept of the dam could be used to adapt at the flume. This will enhance the support structure of the flume hence, more design could be proposed. Even though the M. Ghazavi (2003) did not consider the displacement at the top of the sidewall, new design could be develop to compare with the design recommended by M. Ghazavi.

2.6 DESIGN CONSIDERATION FOR COUNTERFORT WALL

There are various designs of the counterfort wall design. Some were suggesting building the support structure along the flume. This type is known as mass concrete and the material used are concrete. Mass concrete could be used as the support structure of the flume. In term of effectiveness of the support structure, mass concrete would give a similar result to the counterfort wall design. In 1908, John Monash proved that a significant financial saving could be achieved overall.

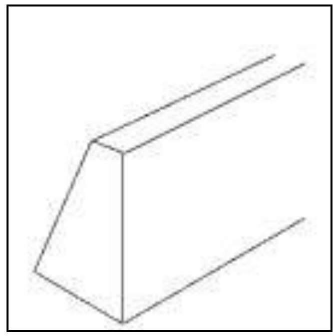

Figure 2.8: Mass concrete

Source: www.vicnet.net.au

Mass concrete also shown that it would require high volume compared to counterfort wall. Therefore, volume of support structure was taken as consideration as it will determine the cost building the support structure. Other than the volume of the support structure, the design from M. Ghazavi will be compared with the new design by changing the parameters of the breadth of support structure, the amount support structure and the length the support structure. Different design will give different result on the displacement of the sidewall of the flume.

All the designs will be referring to the M. Ghazavi counterfort design in Table 2.1. The result of displacement due to changing parameter will be compared to Table 2.1 either the minimum and maximum parameter in M. Ghazavi (2003) is acceptable.